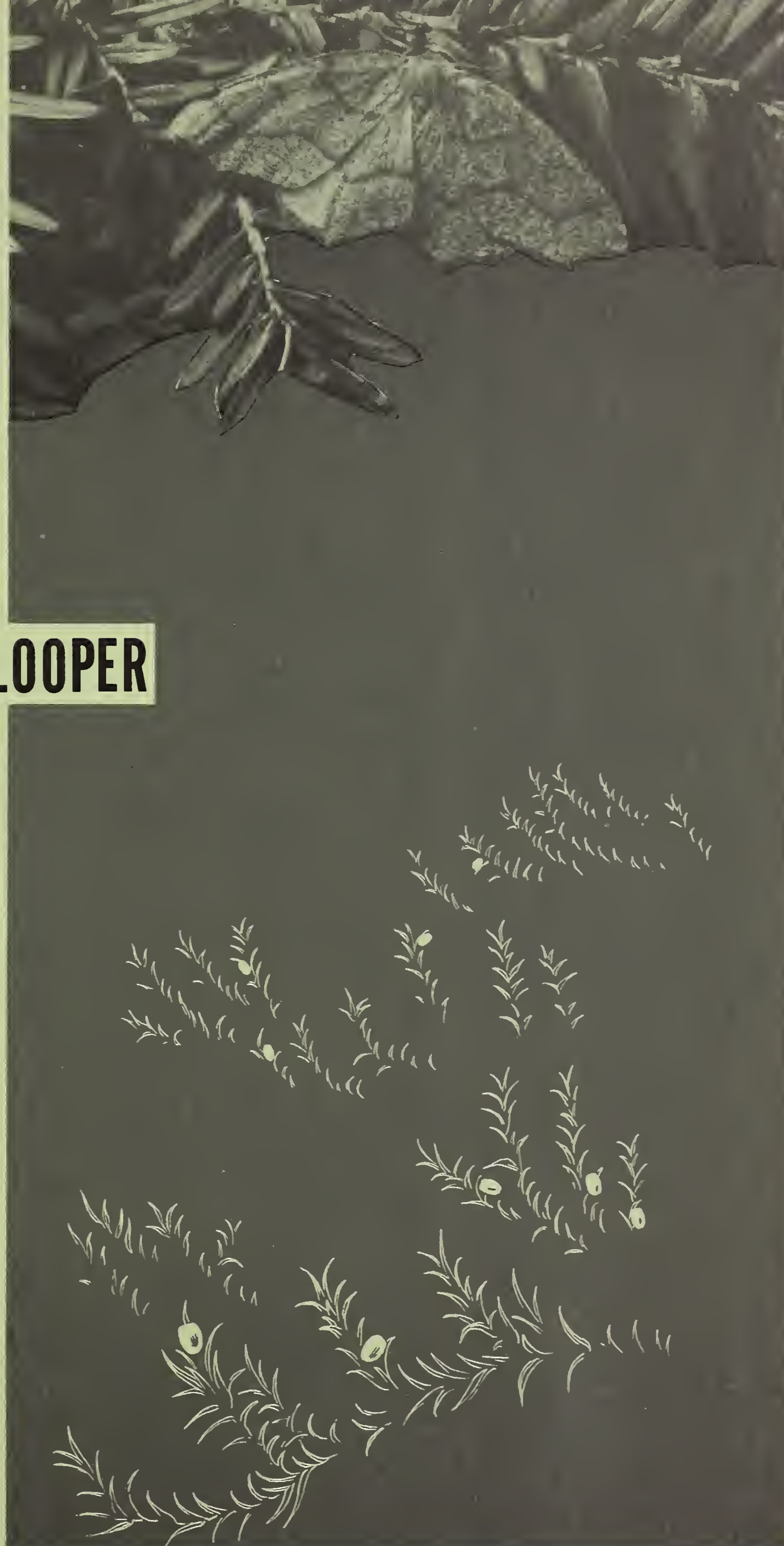
# Sampling egg populations of WESTERN HEMLOCK LOOPER in coastal forests



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## SUMMARY

The western hemlock looper periodically causes severe damage in coastal forests of Oregon, Washington, and British Columbia. Improved survey methods are needed to detect infestations before damage occurs and to express hazard by estimates of egg populations. Cooperative sampling studies by the Forest Service and Weyerhaeuser Co. were conducted in the winter of 1962-63 to improve existing survey techniques.

Results show that the best sampling units for detecting looper infestations are mossy log surfaces and bole sections at breast height, both of which are easily accessible from the ground. Egg deposition is associated with moss on roughened bark and flat lichens on smooth bark. Numbers of eggs found on limbs are related to numbers of eggs on boles, when expressed on the basis of area of moss. The best method for estimating egg populations is to fell the tree and sample the bole at midcrown; this verifies a finding based on studies in British Columbia. Estimating populations in the tree from ground-site samples--a method previously unexplored--does not appear efficient.

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## INTRODUCTION

Outbreaks of western hemlock looper (Lambdina fiscellaria lugubrosa (Hulst)) occur at intervals of 11 to 17 years in coastal areas of Oregon, Washington, and British Columbia. They arise suddenly, persist generally for 3 years, and cause severe damage. Most outbreaks take place in mature stands of western hemlock (Tsuga heterophylla (Raf.) Sarg.). Intermixed Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), Sitka spruce (Picea sitchensis (Bong.) Carr.), Pacific silver fir (Abies amabilis (Dougl.) Forbes), and western redcedar (Thuja plicata Donn) are also attacked. One year's heavy feeding by the looper on western hemlock can result in tree mortality.

If timber losses are to be kept to a minimum, potential outbreaks must be detected at an early stage and evaluated on a biological basis so that direct control can be applied promptly, if needed. By the time hemlock looper damage is visible from the air, an outbreak is usually well underway. Therefore, detection efforts should be aimed at locating appreciable populations before damage occurs, following with a biological evaluation to determine whether tree damage will be significant.

These survey efforts can best be made during the winter by sampling the egg stage. The fact that eggs are deposited on debris and shrubs in the understory area, as well as on overstory trees, causes problems in sampling. Analysis of egg distribution is necessary in order to develop sound sampling techniques for detection and evaluation surveys.

In the past, sampling of egg populations has been directed either to mossy surfaces accessible from the ground or overstory trees, but never to both. In Oregon and Washington, abundance of looper eggs on moss collected at random from various ground locations has been used to indicate relative hazard to stands and probable need for control.[1/] Samples of moss were dried and processed mechanically to separate the eggs from the moss for rapid counting. However, the relation of numbers of eggs found on these samples to populations in overstory trees was not determined. In British Columbia, studies by Thomson[2/] indicated that with relatively low populations the greatest number of eggs on overstory trees occurred on the bole at midcrown. It was recommended that egg sampling be restricted to the bole in the middle part of the crown and

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[1/] Unpublished reports on file U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station and Region 6 National Forest Resource Management, Portland, Oreg.

[2/] Thomson, M. G. Egg sampling for the western hemlock looper. Forestry Chron. 34(3): 248-256. 1958.

that codominant trees be included in the sampling. Earlier, Kinghorn[3] found that egg deposition on tree boles increased with height above ground and reached a maximum density at about the base of the crown. His analysis indicated that, by adjusting butt sample counts with the appropriate regression formula for the total height of the tree, a good estimate of the average number of eggs per sample for the tree should be obtainable. It was pointed out that butt sampling would save a great deal of time by eliminating the task of felling trees but that the method might not be applicable to subepidemic conditions.

Further study of the distribution of looper eggs both on overstory trees and on ground sites (shrubs and debris in the understory area) was needed to (1) improve detection methods and (2) devise a means of estimating the general level of egg populations. These aims were the basis for a cooperative study between the U.S. Forest Service and the Weyerhaeuser Co. during the winter of 1962-63. Results from improvement in sampling techniques are applicable to surveys of current infestations affecting large acreages of valuable hemlock timber in Oregon and Washington.

## OBJECTIVES

This western hemlock looper study was designed to answer the following questions:

1. What sampling unit is best to detect infestations?
2. What are the favored places for egg deposition on codominant western hemlock trees and on ground sites below these trees?
3. Which ground-site samples produce estimates representative of egg deposition on the tree and how do their costs compare with those of samples from the tree crown?

## METHODS

Sampling was restricted to codominant western hemlock trees 20 to 40 inches d.b.h., the common size range in a heavily infested area near Nemah, Wash. The sampling unit was the overstory tree and the area beneath its crown. It was prescribed that at least one understory shrub of huckleberry (*Vaccinium* spp.) and one mossy log occur within the crown projection of each overstory tree. Surveys had previously shown some egg deposition to occur on huckleberries. Subsampling was used to show relative numbers of eggs on the tree at different vertical and horizontal positions and on various representative ground sites. Four trees were sampled as a cluster at each of three locations in the

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[3] Kinghorn, J. M. Western hemlock looper egg sampling. Canada Dept. Agr. Forest Biol. Div. Bimo. Prog. Rpt. 8(3): 3-4. 1952.

infested area. Defoliation of these trees from 1962 feeding, estimated with field glasses, ranged from 10 to 95 percent and averaged about 62 percent. Characteristics of the 12 sample trees are listed in table 1.

Table 1.--Descriptive data on 12 codominant western hemlock trees sampled for hemlock looper eggs near Nemah, Wash., in November and December 1962

| Cluster No. | Tree No. | D.b.h. | Height | | Estimated defoliation |
|---|---|---|---|---|---|
| | | | Total | Base of crown | |
| | | Inches | Feet | Feet | Percent |
| 1 | 1 | 36 | 150 | 80 | 25 |
| | 2 | 31 | 135 | 66 | 80 |
| | 3 | 22 | 120 | 45 | 50 |
| | 4 | 20 | 135 | 70 | 60 |
| 2 | 5 | 38 | 115 | 48 | 90 |
| | 6 | 41 | 135 | 38 | 95 |
| | 7 | 27 | 120 | 45 | 40 |
| | 8 | 21 | 115 | 64 | 10 |
| 3 | 9 | 25 | 120 | 44 | 70 |
| | 10 | 20 | 115 | 45 | 40 |
| | 11 | 34 | 145 | 36 | 90 |
| | 12 | 20 | 120 | 35 | 95 |

The tree was sampled at lower crown, midcrown, and upper crown by taking, at each crown position, three 6-inch-long sections from each of two limbs and two 6x12-inch bark samples from the bole. Limb sections were equally spaced between the base and tip of the branch. In each crown position, limbs and bole areas sampled were on opposite sides of the tree. The bole was also sampled at breast height, using two 6x12-inch sections from opposite sides of the tree. Foliage was not sampled; however, it was inspected since Hopping[4] reported finding some eggs deposited on the undersides of needles. Ground sites sampled were: (1) stem of huckleberry, using three equally spaced 6-inch sections; (2) limb stubs extending vertically from a mossy log, using two 6-inch sections; (3) surface of a mossy log, three 2x4-inch sections; and (4) mossy ground, three 2x4-inch sections.

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[4] Hopping, G. R. An account of the western hemlock looper, *Ellopia somniaria* Hulst, on conifers in British Columbia. Sci. Agr. 15: 12-29. 1934.

Dimensions and numbers of subsample units were selected to equalize examination time for different units and at the same time to obtain appreciable numbers of eggs. Figure 1 shows the sampling scheme diagrammatically.

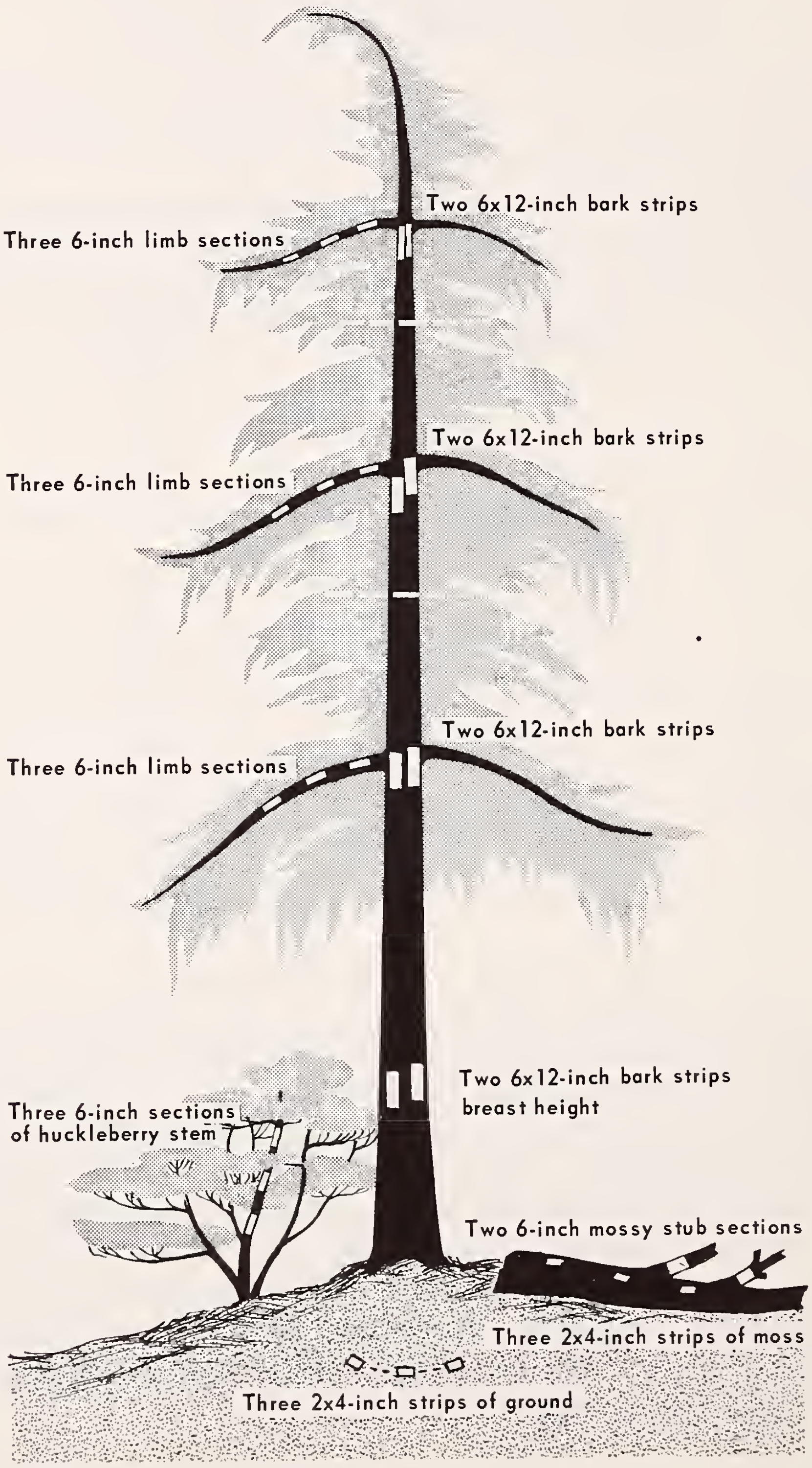


Figure 1.--Diagram of sample tree and its understory area, showing location of subsamples.

Ground sites and boles at breast height were sampled first; then trees were felled and the crowns sampled. Sections of mossy log and mossy ground were cut with a sharp knife and later trimmed to the proper size with scissors. Sections of huckleberry stem, stubs on logs, and limbs on trees were cut with a pruning saw, while bole sections were removed with a chain saw. Examination of subsamples was made with naked eye, stand magnifiers, and binocular microscopes, without testing the accuracy of the three methods. The following data were recorded for each subsample: dimensions of units including average diameter of limb and stem sections, exposure, estimates of percent of "moss" coverage of the sample surface, a rough description of "mosses" and lichens present, numbers of new looper eggs, and time spent in examination. Numbers of old looper eggs were also recorded but not used in any way.

Average costs in man-hours of examining each subsample unit and total costs per site and per tree were determined. Additional cost of felling trees to obtain samples from the tree crown was estimated. Number of eggs on subsamples was expressed in three ways: (1) actual number on subsample, (2) number per 100 square inches of sample surface, and (3) number per 100 square inches of moss.

For detection surveys, subsample costs and variance among trees within clusters were combined to determine the relative efficiency of subsamples. Variance was based on actual numbers of eggs on subsamples. Analysis was aimed at selecting the best subsamples, from the standpoint of cost and variation, for showing whether or not appreciable infestation existed at a sample point.

The abundance of eggs on different substrata (moss, bark scales, lichens) was used as a guide in determining places favored for egg deposition and in selecting the best expression of egg counts for showing relationships between tree and ground locations for evaluation purposes. A tree index was constructed to show average egg populations for each tree. If expression was on the basis of actual number of eggs, the index was obtained by adding all egg counts on limb and bole samples. If expression was either on the basis of gross unit area or moss area, the number of eggs on sampling units was divided by the sum of the area of these units. Use of number of eggs per area, therefore, showed egg density on the sampling units.

Graphs were used to explore the relationship in egg deposition between the tree index and ground-site units, tree units and ground-site units, and boles and limbs within the tree. Correlation analysis was used when relationship appeared possible. Efficiency of using units from ground sites to represent egg populations on overstory trees was briefly explored.

## RESULTS

The various subsample units produced enough looper eggs to facilitate analysis and appeared to include the principal egg deposition sites. Omission of foliage from sampling was justified; no eggs were found on leaves during inspection of felled trees. Numbers of eggs found on the various subsamples taken from the 12 trees are shown in table 2.

Table 2.--Summary of numbers of hemlock looper eggs found and surface area of subsamples from 12 western hemlock trees and ground sites beneath these trees, Nemah, Wash., November-December 1962

| Tree No. | Bole at breast height | | Lower crown | | | | Middle crown | | | | Upper crown | | | | Huckleberry stems | | Stubs on logs | | Mossy logs | | Mossy ground | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Limbs | | Bole | | Limbs | | Bole | | Limbs | | Bole | | | | | | | | | |
| | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area | Eggs | Area |
| | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. | Number | Sq.in. |
| 1 | 58 | 144 | 203 | 165 | 0 | 144 | 337 | 202 | 11 | 144 | 39 | 132 | 7 | 144 | 48 | 41 | 2 | 57 | 3 | 24 | 19 | 24 |
| 2 | 104 | 144 | 40 | 195 | 20 | 144 | 123 | 202 | 48 | 144 | 1 | 162 | 10 | 144 | 2 | 30 | 11 | 57 | 11 | 24 | 3 | 24 |
| 3 | 5 | 144 | 38 | 146 | 29 | 144 | 99 | 156 | 3 | 144 | 20 | 125 | 79 | 144 | 0 | 24 | 14 | 90 | 1 | 24 | 1 | 24 |
| 4 | 22 | 144 | 23 | 151 | 33 | 144 | 27 | 140 | 67 | 144 | 0 | 118 | 1 | 144 | 26 | 57 | 4 | 49 | 3 | 24 | 2 | 24 |
| 5 | 122 | 144 | 222 | 200 | 40 | 144 | 33 | 172 | 64 | 144 | 0 | 130 | 13 | 144 | 121 | 57 | 108 | 28 | 8 | 24 | 6 | 24 |
| 6 | 282 | 144 | 32 | 292 | 101 | 144 | 103 | 261 | 194 | 144 | 9 | 139 | 44 | 144 | 23 | 57 | 61 | 26 | 1 | 24 | 5 | 24 |
| 7 | 101 | 144 | 91 | 203 | 93 | 144 | 40 | 147 | 21 | 144 | 0 | 134 | 8 | 144 | 111 | 42 | 76 | 21 | 2 | 24 | 0 | 24 |
| 8 | 76 | 144 | 14 | 177 | 22 | 144 | 7 | 174 | 1 | 144 | 0 | 129 | 0 | 144 | 1 | 62 | 3 | 28 | 1 | 24 | 0 | 24 |
| 9 | 46 | 144 | 152 | 166 | 173 | 144 | 34 | 145 | 88 | 144 | 0 | 73 | 0 | 144 | 11 | 47 | 4 | 57 | 2 | 24 | 5 | 24 |
| 10 | 44 | 144 | 35 | 139 | 113 | 144 | 55 | 160 | 93 | 144 | 3 | 98 | 25 | 144 | 7 | 24 | 71 | 49 | 1 | 24 | 1 | 24 |
| 11 | 37 | 144 | 29 | 344 | 32 | 144 | 90 | 141 | 10 | 144 | 86 | 154 | 22 | 144 | 10 | 35 | 3 | 47 | 9 | 24 | 2 | 24 |
| 12 | 2 | 144 | 20 | 193 | 11 | 144 | 61 | 153 | 27 | 144 | 6 | 64 | 2 | 144 | 2 | 49 | 5 | 113 | 3 | 24 | 0 | 24 |
| Total | 899 | 1,728 | 899 | 2,371 | 667 | 1,728 | 1,009 | 2,053 | 627 | 1,728 | 164 | 1,458 | 211 | 1,728 | 362 | 525 | 362 | 622 | 45 | 288 | 44 | 288 |
| Average | 74.9 | -- | 74.9 | -- | 55.6 | -- | 84.1 | -- | 52.2 | -- | 13.7 | -- | 17.6 | -- | 30.2 | -- | 30.2 | -- | 3.7 | -- | 3.7 | -- |

Examination of subsamples from the trees and ground sites required about 40 man-hours per tree. Time required to examine two bole sections was similar to that for three ground sections; considerably more time was required to examine a group of six limb sections. On a unit subsample basis, costs in terms of man-hours varied directly with the amount of moss present. Average man-hours required are shown below:

| | Units per tree | For single units | For all units per tree |
|---|---|---|---|
| | (Number) | (Man-hours) | (Man-hours) |
| Limb sites: | | | |
| Lower crown | 6 | 1.55 | 9.30 |
| Midcrown | 6 | 1.18 | 7.08 |
| Upper crown | 6 | .37 | 2.22 |
| Total | | | 18.60 |
| Bole sites: | | | |
| Breast height | 2 | 1.76 | 3.52 |
| Lower crown | 2 | 1.51 | 3.02 |
| Midcrown | 2 | 1.09 | 2.18 |
| Upper crown | 2 | .58 | 1.16 |
| Total | | | 9.88 |
| Ground sites: | | | |
| Stubs on log | 2 | 1.44 | 2.88 |
| Huckleberry stem | 3 | 1.09 | 3.27 |
| Mossy log | 3 | .69 | 2.07 |
| Ground | 3 | 1.05 | 3.15 |
| Total | | | 11.37 |
| Total for sample tree | | | 39.85 |

Sampling for Detection Purposes

Analysis as to relative efficiency or precision of subsample estimates was based on costs and among-tree within-cluster variances. The additional cost of those units obtainable only by felling trees was derived by adding 0.5 man-hour to the examination costs on a tree basis. The analysis showed that two ground-site units--mossy logs and breast-high boles--were superior, for detection purposes, to units in the tree crown.

Variance among trees within clusters was expressed by the coefficient of variation, as shown in the following tabulation:

| | Among-tree coefficient of variation |
|---|---|
| Subsample: | |
| Boles, breast height | 0.81 |
| Boles, lower crown | .89 |
| Limbs, midcrown | .97 |
| Mossy logs | 1.02 |
| Log stubs | 1.06 |
| Limbs, lower crown | 1.09 |
| Boles, midcrown | 1.12 |
| Huckleberry stems | 1.24 |
| Boles, upper crown | 1.43 |
| Ground | 1.47 |
| Limbs, upper crown | 1.93 |

Two of the five units showing the least variation were from ground sites; a third was accessible from the ground. Breast-high bole sections were the least variable, while mossy logs and log stubs ranked fourth and fifth, respectively. Two subsamples from the tree crown--boles in lower crown and limbs at midcrown--were in second and third place.

The precision for each type of sampling unit relative to the precision for mossy logs, as shown below, was calculated by the formula:[5/]

$$\text{Relative precision} = \frac{V_1^2 C_1}{V_2^2 C_2}$$

where $V_1$ = coefficient of variation for mossy logs

$C_1$ = cost per single mossy log unit on a tree basis

$V_2$ = coefficient of variation for another type of sampling unit

$C_2$ = cost per single sampling unit of this other type on a tree basis.

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5/ Based on: Cochran, W. G. Sampling techniques. Ed. 2, 413 pp. New York and London: John Wiley & Sons, Inc.

| | Relative precision |
|---|---|
| Subsample: | |
| Mossy logs | 100 |
| Boles, breast height | 93 |
| Boles, lower crown | 77 |
| Log stubs | 67 |
| Boles, midcrown | 64 |
| Boles, upper crown | 63 |
| Huckleberry stems | 43 |
| Ground | 32 |
| Limbs, midcrown | 30 |
| Limbs, upper crown | 21 |
| Limbs, lower crown | 18 |

The two units most efficient for use in detection surveys--mossy logs and breast-high boles--are both accessible from the ground. If trees were being felled for another purpose, such as right-of-way clearing, bole sections from the lower crown could be efficiently used. Use of log stubs might be justified if expense of transporting subsamples through the woods is high.

Standards for use in detection surveys to distinguish between endemic and epidemic populations are lacking. Since sampling was done under epidemic conditions in this study, the following estimates from table 2 can be used as a guide in recognizing an epidemic population level.

| | Subsample components | | Number of eggs | |
|---|---|---|---|---|
| | Number | Dimensions | Average | Range |
| Subsample: | | | | |
| Mossy logs | 3 | 2x4 inches | 4 | 1-11 |
| Boles, breast height | 2 | 6x12 inches | 75 | 2-282 |
| Boles, lower crown | 2 | 6x12 inches | 56 | 0-173 |
| Log stubs | 2 | 6-inch sections | 30 | 2-108 |
| Boles, midcrown | 2 | 6x12 inches | 52 | 1-194 |

## Favored Places for Egg Deposition

On the tree, eggs were found on mosses, on the undersides and edges of flat lichens, and under bark scales. Moss aggregations were usually associated with roughened, scaly bark, whereas lichens were present on smooth bark, usually high in the tree. Very few eggs were found on areas consisting only of bark scales. On ground sites, eggs were found chiefly on true mosses and only occasionally on clubmosses and liverworts. On all sites, true mosses were clearly preferred for egg deposition.

The association of egg deposition with moss indicated that the best expression of egg numbers for evaluation purposes would be on the basis of unit areas

of moss; i.e., 100 square inches. Distribution of eggs was interpreted on this basis and the term "egg density" applied. Since flat lichens were acceptable for egg deposition but usually occurred on the tree where mosses were absent, these were included with mosses to construct egg density.

The midcrown area had the greatest concentration of eggs on moss. Midcrown and upper-crown boles had similar egg densities; however, the actual number of eggs on upper-crown boles was small. Midcrown limbs had a higher egg density than limbs in the other two crown levels. Egg density on moss in the tree crown was generally higher than egg density on moss in ground locations. Data are shown in table 3.

Table 3.--Moss coverage and density of eggs on moss for subsamples removed from 12 western hemlock trees near Nemah, Wash., November-December 1962

| Subsample unit | Totals for all subsamples | | | | Eggs per 100 square inches of moss (average) |
|---|---|---|---|---|---|
| | Surface area of subsamples | Eggs | Surface area of moss | | |
| | Sq. in. | Number | Percent | Sq. in. | Number |
| Tree sites: | | | | | |
| Limbs: | | | | | |
| Lower crown | 2,371 | 899 | 67 | 1,589 | 57 |
| Midcrown | 2,053 | [1]1,006 | 48 | 985 | 102 |
| Upper crown | 1,458 | 164 | 13 | 189 | 87 |
| Boles: | | | | | |
| Lower crown | 1,728 | 667 | 34 | 587 | 114 |
| Midcrown | 1,728 | 627 | 22 | 380 | 165 |
| Upper crown | 1,728 | 211 | 7 | 121 | 174 |
| Breast height | 1,728 | 899 | 50 | 864 | 104 |
| Total | 12,794 | 4,473 | -- | 4,715 | -- |
| Average | -- | -- | -- | -- | 95 |
| Ground sites: | | | | | |
| Stubs on logs | 622 | 362 | 72 | 448 | 81 |
| Huckleberry stems | 525 | 362 | 78 | 410 | 88 |
| Mossy logs | 288 | 45 | 96 | 276 | 16 |
| Mossy ground | 288 | 44 | 89 | 256 | 17 |
| Total | 1,723 | 813 | -- | 1,390 | -- |
| Average | -- | -- | -- | -- | 58 |

1/ Three eggs on a subsample with no moss are omitted.

Vertical surfaces had higher egg densities than nearby horizontal surfaces, both within the crown and on ground locations. At each crown position, boles had about twice the egg density of limbs, even though moss coverage on boles was half that of limbs. On the ground, log stubs and huckleberry stems had about five times as many eggs per unit area of moss as did log surfaces and mossy ground. Moss coverage was slightly higher on the log and ground surfaces. Although moss was preferred for egg deposition, beyond a certain minimum area of coverage (approximately 20 percent) the actual amount had little bearing on the amount of egg deposition.

## Tree Site-Ground Site Relationships

Although the advantages of expressing density of eggs on a moss-area basis were apparent, the other two expressions (number of eggs on subsamples and number of eggs per unit area of subsample surface) were also used to test relationships graphically. In all cases, scatter was less when egg density on moss was used, even though most relationships were not statistically significant.

Use of a tree index (with eggs on moss) was enhanced when egg density on limbs was found correlated with that on boles. Separate analyses by crown position showed correlation at the 1-percent level between limbs and boles at both midcrown and upper crown. Correlation for the lower crown failed because of nonconforming estimates on one tree. Relationships are shown in figure 2.

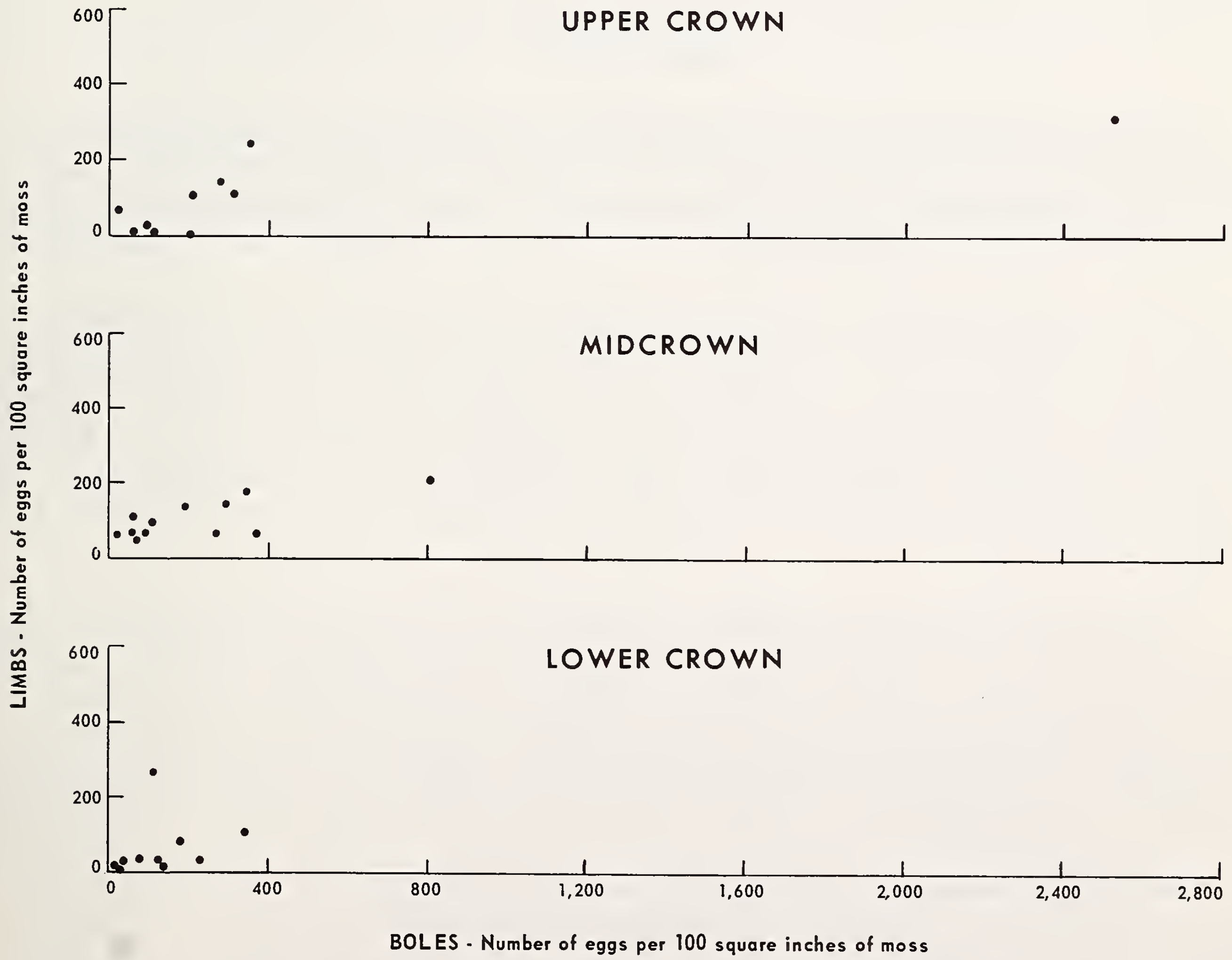


Figure 2. --Relationship between egg densities on limbs and boles of western hemlock.

No definite relationship was found between egg densities on tree sites and ground sites. None of the various ground-site or breast-high-bole samples could be correlated with the tree index, midcrown boles, or midcrown limbs. Egg densities on breast-high boles and various ground-site units were unrelated.

Two combinations of ground-site samples, having similar egg densities, were tested for correlation with the tree index. With mossy ground + mossy log surface, correlation was approached ($r = 0.516$) at the 5-percent level. With huckleberry stems + log stubs, no correlation was evident.

Comparison was made of mossy ground + mossy log surface with midcrown boles for relative efficiency in sampling. On the former, the mean egg density for 12 trees was 17.1 ± 4.6, the standard error being 27 percent of the mean. For confidence in this estimate ($P = 0.05$), approximately 50 trees should be sampled at a cost of 5.22 man-hours per tree for examination. On midcrown boles the mean was 233.6 ± 80.6, the standard error being 34.5 percent of the mean. For a standard error of 27 percent ($P = 0.05$), 73 paired bole samples should be taken at a cost of 2.2 man-hours per tree for examination plus 0.5 man-hour for felling the tree. Costs of using midcrown boles are 64 man-hours less than the mossy ground + log sample. This shows that, for evaluation purposes, felling trees is justified in order to get precise population estimates.

## DISCUSSION

In this study, estimates of man-hours were based on visual examination of subsample units. While it is likely that mechanical processing will reduce costs of examining most kinds of samples, the relative efficiency of the various samples will be mainly unchanged.

It is important that sampling for detection purposes be recognized as distinct from other kinds of sampling. Sampling techniques for detection are meant to show quickly and precisely whether appreciable infestation exists at a sample point or plot and to outline areas requiring evaluation surveys. Criteria, expressed as number of eggs found, vary with the choice of sampling unit. The egg counts obtained should not be construed as indices of the population levels on overstory trees.

Evaluation of egg populations on overstory trees can apparently be done only by felling trees. This creates a problem in attempting to establish standards for evaluation surveys, particularly in relating populations to subsequent damage. Further study of the mossy log + mossy ground combination is needed to determine whether or not larger samples will show a higher correlation with populations in trees and whether mechanical processing will reduce costs appreciably.

Physical obstacles in sampling inaccessible areas must be considered. In detection surveys, because of varying costs involved in hauling samples through the woods, some flexibility as to choice of sample units is advisable.

On the other hand, surveys to estimate population levels on overstory trees leave no alternative to the cutting of trees for sampling boles at midcrown.

## CONCLUSIONS

The best sampling units for detecting looper infestations, when visual examination is required, are mossy log surfaces and bole sections at breast height. Because numbers of eggs found on log surfaces are low, increasing the number of 2x4-inch subsamples might be desirable if method error is appreciable. Cost factors not considered in this study, such as that of transporting samples through the woods, might enhance the relative efficiency of log stubs.

Egg deposition is clearly associated with moss on roughened bark and with flat lichens on smooth bark; also, vertical surfaces have more eggs per unit area of moss than horizontal surfaces.

Egg density on moss is greatest on the bole in the upper and middle crown, followed by the bole in the lower crown and at breast height, limbs at midcrown, huckleberry stems, upper limbs, log stubs, and lower limbs. The midcrown area has the greatest concentration of eggs.

Correlations between egg densities on limbs and boles within the crown indicate that either may be used as an index of tree populations. Boles at mid-crown are a logical choice, since density of eggs on moss is greater than on other samples and examination costs are low.

Estimating tree populations from ground-site samples is not shown feasible. While one combination of ground-site samples showed borderline correlation with tree populations, costs are greater than felling the tree and sampling midcrown boles.

Carolin, V. M., Johnson, N. E., Buffam, P. E., and McComb, D.
1964. Sampling egg populations of western hemlock looper in coastal forests. U.S. Forest Serv. Res. Paper PNW-14, 13 pp., illus.

Distribution of eggs on overstory trees and ground sites was studied in order to improve survey techniques in detecting and evaluating infestations. The best sampling units for detection were mossy log surfaces and breast-high bole sections. The best method for estimating populations on overstory trees was to fell the tree and sample the bole at midcrown.

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